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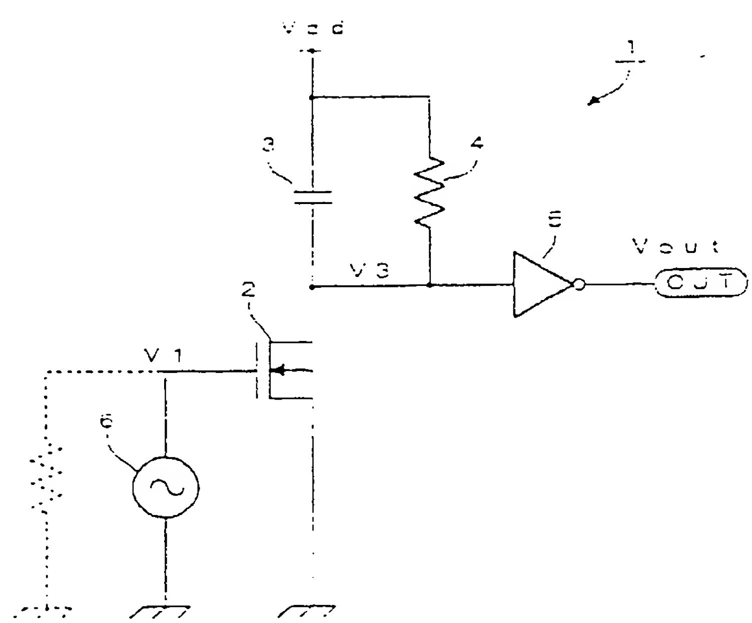
(57) There is provided a power-generation detection circuit which can detect a power-generation state by an AC voltage supplied from a power-generation device, and an electronic device having the power-generation detection circuit. A power-generation detection circuit constituted by a capacitor 3, and a MOS transistor 2, a resistor 4, and an inverter circuit 5 which controls charging of the capacitor by a generation voltage from a power-generation device 6. The MOS transistor is switched by an AC voltage from the power-generation device 6. The voltage of the capacitor is detected by the inverter circuit to perform power-generation detection.

[FIG. 2]



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Description

The present invention relates to a power-generation detection circuit of an electronic device which can be driven by an AC power generated by motion of a rotating weight or motion of a spring, a semiconductor device in which the power-generation detection circuit is formed, an electronic device having the power-generation detection circuit, a timepiece, a power-generation detection method, and a power consumption control method.

In a compact electronic device such as a wrist watch suitable for portability, an electronic device which incorporates a power-generation device therein to obtain a power for driving the electronic device without a battery has been devised and practically used. FIG. 15 shows the basic arrangement of an electronic device which incorporates an electromagnetic generator 6 as an example. This portable electronic device comprises an electromagnetic power-generation device as the power-generation device 6. This portable electronic device comprises a rotating weight 7 performing swing motion in the electronic device, a train wheel mechanism 8 for transmitting rotating motion of the rotating weight 7 to the electromagnetic generator, and a stator 9 and a rotor 10 which constitute the electromagnetic generator. When the rotor 10 rotates, electromotive force is generated by an output coil 11 of the stator 9, so that an AC power can be extracted. In addition, the AC power output from the electromagnetic generator 6 is entirely rectified by a rectification diode bridge 12 to supply the power to a large-capacity capacitor 13 and a circuit unit 14 of the electronic device. When no power generation is performed by the electromagnetic generator 6, the circuit unit 14 is driven by power stored in the large-capacity capacitor 13. For this reason, this portable electronic device can continuously operate the circuit unit 14 without any battery.

This electronic device has no means for detecting the state of power generation supplied from the power-generation device 6 and the current consumption of the circuit unit 14 is constant regardless of the state of power generation of the power-generation device 6. For this reason, even if no power is being generated, since power is consumed in the circuit unit 14, the large-capacity capacitor 13 performs a discharging operation within a short period of time. As a result, a problem arises in that the circuit unit 14 can come to a complete stop.

It is an object of the present invention to provide a power-generation detection circuit which can detect the state of power-generation (presence/absence of power generation and strength of power generation) supplied from a power-generation device of an electronic device by a simple method and can control power consumption of a circuit unit depending on the detected state of generation power. It is an object of the invention similarly to provide a semiconductor device, an electronic device, a timepiece, a power-generation detection method, and a power consumption control method

In order to solve the above problem, a power-generation detection circuit according to the invention of claim 1 is characterised by comprising: switching means for performing a switching operation depending on a cycle of an AC power which is externally generated: a capacity element for storing charges depending on a switching operation performed by said switching means: discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element; and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value.

In the invention according to claim 2, a power-generation detection circuit according to claim 1 is characterised in that said discharging means is a resistor element.

In the invention according to claim 3, a power-generation detection circuit according to claim 1 is characterised in that said discharging means is constituted by a constant-current circuit.

In the invention according to claim 4, a power-generation detection circuit according to claim 3 is characterised in that said constant-current circuit is constituted by a constant-current source and a current mirror circuit.

In the invention according to claim 5, a power-generation detection circuit according to claim 1 is characterised by comprising a current-limiting means, connected in series with said capacity element, for limiting a charge current of said capacity element

In the invention according to claim 6, a power-generation detection circuit according to claim 1 is characterised in that said voltage detection means is an inverter circuit.

In the invention according to claim 7, a power-generation detection circuit according to claim 1 is characterised in that said voltage detection means is a Schmidt trigger inverter circuit.

In the invention according to claim 8, a power-generation detection circuit according to claim 1 is characterised in that said voltage detection circuit is a comparator circuit.

In the invention according to claim 9, a power-generation detection circuit according to claim 1 is characterised in that said switching means is a transistor

In the invention according to claim 10 a power-generation detection circuit according to claim 9 is characterised in that said transistor is a MOS transistor.

In the invention according to claim 11, a power-generation detection circuit according to claim 9 is characterised in that said transistor is a bipolar transistor

In order to solve the above problem, a semiconductor device according to the invention of claim 12 is characterised by comprising: switching means for performing a switching operation depending on a cycle of an AC power which is externally generated; a capacity element for storing charges depending on a switching operation performed by said switching means discharging means, inserted in a discharging path of said capacity

element, for discharging the charges stored in said capacity element and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value.

In the invention according to claim 13, a semiconductor device according to claim 12 is characterised in that said discharging means is constituted by a constant-current source and a current mirror circuit.

In the invention according to claim 14, a semiconductor device according to claim 12 is characterised in that said current mirror circuit is a pair of transistors.

In the invention according to claim 15, a semiconductor device according to claim 12 is characterised in that said switching means is a transistor.

In the invention according to claim 16, a semiconductor device according to claim 12 is characterised in that said transistor is a MOS transistor.

In the invention according to claim 17, a semiconductor device according to claim 12 is characterised in that said transistor is a bipolar transistor.

In order to solve the above problem, an electronic device according to the invention of claim 18 is characterised by comprising: a power-generation device for generating an AC power; and a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device, a capacity element for storing charges depending on a switching operation performed by said switching means, discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value.

In the invention according to claim 19, an electronic device according to claim 18 is characterised in that said power-generation device has a rotating weight for performing swing motion and a power-generation element for generating electromotive force by rotating motion performed by said rotating weight.

In the invention according to claim 20, an electronic device according to claim 18 is characterised in that said power-generation device has an elastic member on which deformation force acts, rotating means for performing rotating motion by recovery force generated by causing said elastic member to return to an original shape, and a power-generation element for generating electromotive force by the rotating motion of said rotating means.

In the invention according to claim 21, an electronic device according to claim 18 is characterised in that said power-generation device has a piezoelectric element which generates electromotive force by a piezoelectric effect when displacement acts on said piezoelectric element.

In order to solve the above problem, an electronic device according to the invention of claim 22 is characterised by comprising: a power-generation device for generating an AC power; a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device, a capacity element for storing charges depending on a switching operation performed by said switching means, discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value; and a control circuit for controlling power consumption of said device on the basis of a detection result of said voltage detection means.

In the invention according to claim 23, an electronic device according to claim 22 is characterised in that said control circuit determines that said power-generation device does not perform power generation when a voltage of said capacity element is not more than the predetermined value, and reduces power consumption of said device.

In the invention according to claim 24, an electronic device according to claim 23 is characterised in that said control circuit determines that said power-generation device is performing power generation when a voltage of said capacity element exceeds the predetermined value, and cancels the reduction in power consumption.

In the invention according to claim 25, an electronic device according to claim 22 is characterised in that said control circuit controls the power consumption of said device in consideration of the length of time in which a voltage of said capacity element exceeds the predetermined value.

In order to solve the above problem, a timepiece according to the invention of claim 26 is characterised by comprising: a power-generation device for generating an AC power; a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device, a capacity element for storing charges depending on a switching operation performed by said switching means, discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value; and a timer circuit for counting time.

In the invention according to claim 27, a timepiece according to claim 26 is characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a wrist watch.

In the invention according to claim 28, a timepiece according to claim 26 is characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a pocket watch.

In the invention according to claim 29, a timepiece according to claim 26 is characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a table timepiece.

In order to solve the above problem, a power-generation detection method according to the invention of claim 30 is characterised by comprising: the first step of performing a charging operation to a capacity element by a switching operation depending on a cycle of an AC power which is externally generated; the second step of performing a discharging operation of said capacity element when a charging operation is not performed to said capacity element; the third step of determining whether a voltage of said capacity element is a predetermined voltage; and the fourth step of determining that power generation is performed when the voltage exceeds the predetermined voltage.

In order to solve the above problem, a power consumption control method according to the invention of claim 31 is characterised by comprising: the first step of performing a charging operation to a capacity element by a switching operation depending on a cycle of an AC power which is externally generated; the second step of performing a discharging operation of said capacity element when a charging operation is not performed to said capacity element; the third step of determining whether a voltage of said capacity element is a predetermined voltage; the fourth step of determining that no power generation is performed when the voltage does not exceed the predetermined voltage; and the fifth step of reducing power consumption of a circuit unit when no power generation is performed.

In the invention according to claim 32, a power consumption control method according to claim 31 is characterised by comprising: the sixth step of determining whether time in which the voltage exceeds the predetermined voltage continues for a predetermined period of time; and the seventh step of cancelling a reduction in power consumption of said circuit unit when the time continues for the predetermined period of time.

Embodiments of a power-generation detection circuit according to the present invention will be described below by way of further example only and with reference to the accompanying drawings.

FIG. 1 is a circuit block diagram showing the basic arrangement of an electronic device to which a power-generation detection circuit according to the present invention is applied.

FIG. 2 is a circuit diagram showing an arrangement of a power-generation circuit according to the present invention.

FIG. 3 is a timing chart for explaining an operation of a power-generation detection circuit according to the present invention.

FIG. 4 is a circuit block diagram showing the basic arrangement of a power-generation detection circuit according to Embodiment 2 of the present invention

FIG. 5 is a circuit block diagram showing the basic arrangement of a power-generation detection circuit according to Embodiment 3 of the present invention.

FIG. 6 is a circuit block diagram showing the basic arrangement of a power-generation detection circuit according to Embodiment 4 of the present invention.

FIG. 7 is a circuit block diagram showing the basic arrangement of a power-generation detection circuit according to Embodiment 5 of the present invention.

FIG. 8 is a circuit block diagram showing the basic arrangement of a power-generation detection circuit according to Embodiment 6 of the present invention.

FIG. 9 is a concept chart showing V1 which is output from an electromagnetic generator 6 and changes depending on a change in rotating speed of a rotor 10 according to Embodiment 7 of the present invention and shows a power-generation detection signal Vout for V1.

FIG. 10 is a concept chart showing V1 which is output from an electromagnetic generator 6 according to Embodiment 8 of the present invention and shows a power-generation detection signal Vout for V1.

FIG. 11 is a circuit diagram showing the basic arrangement of a power supply block according to Embodiment 9 of the present invention.

FIG. 12 is a concept chart showing the waveforms of V1 and V2 which are output from an electromagnetic generator according to Embodiment 9 of the present invention.

FIG 13 is a circuit diagram showing the arrangement of a power-generation detection circuit according to Embodiment 9 of the present invention.

FIG. 14 is a concept chart for explaining an application of a power-generation detection circuit 1 of the present invention.

FIG. 15 is a schematic view showing the arrangement of a power supply block of an electronic device having a power-generation device.

(Embodiment 1)

FIG. 1 is a circuit block diagram showing the basic arrangement of an electronic device to which a power-generation detection circuit according to the present invention is applied. The same reference numerals are used in FIG. 1 as denote the same parts in FIG. 15, and a detailed description thereof will be omitted. Referring to FIG. 1, the electronic device is constituted by a power-generation detection circuit 1, a power save control circuit 30, a power-generation device 6, a rectification diode bridge 12, a large-capacity capacitor 13, and a circuit unit 14. The basic arrangement of the power-generation detection circuit 1 is shown in FIG. 2. In FIG. 2, the power-generation detection circuit 1 of this embodiment is connected to the power-generation device 6, and is constituted by a MOS transistor 2, a capacitor 3, a pull-up resistor 4, and an inverter circuit 5

A signal from a power-generation device 6 is connected to the gate of the MOS transistor 2, and the MOS

transistor 2 repeats an ON/OFF operation in response to a generated AC voltage V1 to control charging of the capacitor 3. When the switching means is constituted by a MOS transistor, a power-generation detection circuit 1 including the inverter circuit 5 can be constituted by an inexpensive CMOS-IC. However, the switching element and the voltage detection means may be constituted by bipolar transistors. The pull-up resistor 4 functions to fix a voltage value V3 of the capacitor 3 to a Vdd potential in a no-power-generation state and generate a leakage current in the no-power-generation state. The pull-up resistor 4 has a high resistance of about several tens to several hundreds MW, and may also be constituted by a MOS transistor having a high ON resistance. The voltage value V3 of the capacitor 3 is determined by the inverter circuit 5 connected to the capacitor 3. If a power-generation state is set, the inverter circuit 5 outputs a power-generation detection signal Vout to be "HI".

Although a low-voltage side Vss of the circuit is shown as a reference voltage in this embodiment, as used in many wrist watch circuits, a high-voltage side Vdd may be used as a reference without any problem. In addition, an AC voltage V1 of the power-generation device 6 may be connected to Vss through a high-resistance resistor to make a potential in a no-power-generation state stable. In addition, in order to turn off an Nchannel MOS transistor in a no-power-generation state, an output voltage V1 of the power-generation device in the no-power-generation state must be made stable at Vss, and V1 is preferably connected to Vss through a resistor element.

The power save control circuit 30 sends a control signal S1 to the circuit unit 14 according to the power-generation detection signal Vout from the inverter circuit 5 of the power-generation detection circuit 1 to switch the circuit unit 14 to a power save mode. When the circuit unit 14 receives the control signal S1, the circuit unit 14 determines the power save mode is set, and cuts a power supply to a mechanical driver or some functions of the circuit to reduce power consumption. In the power save mode, when a timepiece (especially, a wrist watch) is used as an electronic device to be applied, for example, moving of needles may be stopped or a power supply to some functions of the circuit (e.g., a sensor function, a chronograph function, and a liquid-crystal display function) may be turned off.

An operation of the power-generation circuit according to this embodiment will be described below with reference to the timing chart shown in FIG. 3. When generation of an AC power is started by the power-generation device 6, an AC signal which has an amplitude of 'Vdd + VF (forward voltage of a rectification diode) to 'Vss - VF' appears at a one terminal V1 of the power-generation device 6. A signal having a phase opposing the phase of V1 and the same amplitude as that of V1 appears at the other terminal V2 of the power-generation device. When generation is started, and the voltage V1 rises from Vss to Vdd, the MOS transistor 2 is turned on to start charging of the capacitor 3. The potential of V3 is fixed to the Vdd side by the pull-up resistor 4 in a no-power-generation state. However, when the power generation occurs to start charging of the capacitor 3, the potential of V3 begins to fall to the Vdd side. When the voltage of V1 decreases to Vss, and the MOS transistor 2 is turned off, charging to the capacitor 3 is stopped. However, the potential of V3 is kept constant by the capacitor 3. The above operation is repeated while generation continues, and the potential of V3 decreases to Vss to be stable. When the potential V3 is lower than the threshold value of the inverter circuit 5, the power-generation detection signal Vout serving as an output from the inverter circuit 5 is switched from "LOW" to "HI", and generation can be detected. Response time until generation is detected can be arbitrarily set by connecting a current-limiting resistor, by changing the capability of the MOS transistor to adjust the value of a charge current for the capacitor 3, or changing the capacitance of the capacitor 3.

When the power generation is stopped, since V1 is stable at a Vss level, the MOS transistor 2 is kept in an OFF state. The voltage of V3 is continuously held for a while by the capacitor 3. However, since charges of the capacitor 3 are discharged by a small leakage current generated by the pull-up resistor 4, V3 begins to gradually increase from Vss to Vdd. When V3 exceeds the threshold value of the inverter circuit 5, the power-generation detection signal Vout serving as an output from the inverter circuit 5 is switched from "LOW" to "HI", a no-power-generation state can be detected. This response time can be arbitrarily set by changing the resistance of the pull-up resistor 4 and adjusting the leakage current of the capacitor. When the power-generation detection signal Vout serving as an output from the inverter circuit 5 is monitored as described above, the state of power generation can be detected.

Therefore, if the state of power generation can be detected, setting/cancelling of a power save mode is switched with respect to the circuit unit 14 by the power save control circuit 30 depending on the state, and operation time in no-power-generation state can be elongated by suppressing power consumption.

(Embodiment 2)

FIG. 4 shows an embodiment of the present invention and an example wherein a current-limiting resistor 15 is connected in series with a capacitor 3. Since this embodiment has almost the same arrangement as that in FIG. 2, the same reference numerals as in FIG. 2 denote the same parts in FIG. 4. A charge current of the capacitor 3 when a MOS transistor 2 is turned on and response time until a power-generation detection signal is output can be adjusted by changing the value of the current-limiting resistor 15. As in this embodiment, when the current-limiting resistor 15 is connected, a charge

current to the capacitor 3 decreases. For this reason, a longer time is required to make a capacitor voltage V3 lower than the threshold voltage of the inverter, and the time until a power-generation detection signal is output becomes long.

(Embodiment 3)

FIG. 5 shows an embodiment of the present invention and an example wherein a switching MOS transistor is constituted by a P-channel MOS transistor 16. The positions of a capacitor and a MOS transistor are reversed to those in the arrangement of an N-channel MOS transistor shown in FIG. 2 with respect to a power supply voltage. Since this embodiment has almost the same arrangement as that in FIG. 2, the same reference numerals as in FIG. 2 denote the same parts in FIG. 5. In this arrangement, in order to turn off the P-channel MOS transistor 16 in a no-power-generation state, an output voltage V1 of the power-generation device in a no-power-generation state must be stable at Vdd, and V1 is preferably connected to Vdd through a resistor. As this resistor, a MOS transistor having a high ON resistance may be used.

(Embodiment 4)

FIG. 6 shows an embodiment of the present invention and an example wherein a pull-up resistor is constituted by a constant-current circuit Since this embodiment has almost the same arrangement as that in FIG. 2, the same reference numerals as in FIG. 2 denote the same parts in FIG. 6. A constant-current circuit is constituted by a current mirror circuit constituted by a constant-current source 17 and MOS transistors 18 and 19, and a slight constant current flows from Vdd to V3. In order to hold outputting of a power-generation detection signal Vout for a long period of time, a leakage current of the capacitor must be reduced, and the resistance of the pull-up resistor considerably increases. In this case, a variation in resistance is enlarged, and output holding time of a power-generation detection signal Vout has characteristics having a large variation. When the generating detection circuit is constituted by the constant-current circuit as in this embodiment, a small leakage current value such as several nA can be set, and a variation in leakage current can be advantageously made considerably smaller than that in the arrangement wherein the generating detection circuit is constituted by a resistor.

(Embodiment 5)

FIG. 7 shows an embodiment of the present invention and an example wherein a voltage detection means is constituted by a Schmidt trigger inverter circuit. Since this embodiment has almost the same arrangement as that in FIG 2, the same reference numerals as in FIG 2 denote the same parts in FIG. 7. When the voltage detection means is constituted by a Schmidt trigger inverter circuit 20 having hysteresis characteristics, stable power-generation detection can be advantageously performed without being influenced by an instantaneous variation in voltage V3 of a capacitor.

(Embodiment 6)

FIG. 8 shows an embodiment of the present invention and an example wherein a voltage detection means is constituted by a comparator circuit 21. Since this embodiment has almost the same arrangement as that in FIG. 2, the same reference numerals as in FIG. 2 denote the same parts in FIG. 8. The comparator circuit 21 compares an output voltage V4 from a reference voltage generation circuit 22 with a capacitor voltage V3. If V3 is lower than V4, the comparator circuit 20 outputs a power-generation detection signal to be "HI".

In the electronic device comprising the generator shown in FIG. 2, a power supply voltage changes depending on the charging state of the large-capacity capacitor 13 and varies depending on the voltages at both the ends of the large-capacity capacitor 13. When the voltage detection means is constituted by an inverter, the threshold voltage of the inverter changes to be interlocked with a variation in power supply voltage Vdd. For this reason, power-generation detection time also varies When the voltage detection means is constituted by the comparator circuit 21 as in this embodiment, the threshold value of power-generation detection is kept constant without being influenced by a variation in power supply voltage, and stable detection at a high precision can be realised.

(Embodiment 7)

FIG. 9 is a concept chart showing V1 which is output from an electromagnetic generator 6 and changes depending on a change in rotating speed of a rotor 10 and a power-generation detection signal Vout for V1. In particular, FIG. 9(a) shows a case wherein the rotating speed of the rotor 10 is low, and FIG. 9(b) shows a case wherein the rotating speed of the rotor 10 is high. The voltage level and cycle (frequency) of V1 output from the electromagnetic generator 6 change depending on the rotating speed of the rotor 10. More specifically, as the rotating speed is higher, the voltage level of V1 is high, and the cycle is shortened. For this reason, the length of output holding time (ON time) of the power-generation detection signal Vout changes depending on the strength of power generation of the electromagnetic generator 6. More specifically, when the output V1 slightly changes as in FIG. 9(a), the output holding time is represented by tl; when the output V1 change is large as in FIG. 9(b), the output holding time is represented by t2 The output holding times tl and t2 satisfy the relationship t1 < t2 As described above according to the

length of the output holding time of the power-generation detection signal Vout the strength of power generation of the electromagnetic generator 6 can be known. Embodiment 7 described above can also be applied to Embodiments 1 to Embodiment 6 described above, as a matter of course.

(Embodiment 8)

FIG. 10 is a concept chart showing V1 which is output from the electromagnetic generator 6 and changes depending on a shaking manner of a wrist watch when the electromagnetic generator 6 is applied to the wrist watch or the like, and a power-generation detection signal Vout for V1. For example, when the power-generation detection circuit 1 is applied to a wrist watch, the rotating speed of the rotor 10 changes depending on the motion of a user. More specifically, when the user strongly shakes the watch with his/her hand or strongly shakes his/her hand with the watch attached, as described above, the output holding time of the power-generation detection signal Vout becomes long. In contrast to this, when the user does not strongly shake the watch, the output holding time of the power-generation detection signal Vout becomes short. Therefore, when it is detected whether the output holding time of the power-generation detection signal Vout continues for a predetermined period of time, it can be known whether the user strongly shakes the watch (wrist watch) or not. In this case, when the OFF state of the power-generation detection signal Vout continues to set a power save mode, if the output holding time of the power-generation detection signal Vout continues for the predetermined period of time, it is determined that the user cancels the power save mode, and the power save mode may be automatically cancelled.

However, the following is known. That is, when the user strongly shakes the watch, as shown in FIG. 10(a), a rotating weight 7 is irregularly rotated. V1 serving as an output from the electromagnetic generator 6 has two amplitude peaks. In this case, when the capacity of a capacitor 3 is small, or when the resistance of a pull-up resistor 4 inserted in the discharging path of the capacitor 3 is low, and a discharge current is large, the power-generation detection signal Vout is temporarily discontinued at the trough between the two peaks. Therefore, the strength of power generation is not in proportion to the output holding time of the power-generation detection signal Vout, and the power save mode is not cancelled according to the intention of a user.

In Embodiment 8 described above, the capacity of the capacitor 3 increases to prevent the power-generation detection signal Vout from being discontinued. FIG. 10(b) is a concept chart showing V1 obtained when a user strongly shakes a wrist watch to which the electromagnetic generator 6 is applied when the capacity of the capacitor 3 is increased, and a power-generation detection signal Vout for V1. As shown in FIG. 10(b), when the capacity of the capacitor 3 is increased, charges are suppressed from being reduced at the trough between two peaks, and it can be understood that the power-generation detection signal Vout continues without any discontinuation. Therefore, the output holding time of the power-generation detection signal Vout corresponds to the strength of power generation, and the power save mode can be correctly switched.

In this manner, an improvement in the capacity of the capacitor 3 described above is effective especially when, in cancelling the power save mode, the wrist watch is strongly shaken by a user so as to ensure that the power save mode is cancelled according to his/her intention.

Although Embodiment 8 described above is applied to the arrangement of Embodiment 1, Embodiment 8 may be applied to not only the arrangement of Embodiment 1, but also the arrangement of Embodiment 2 to Embodiment 7 as a matter of course.

(Embodiment 9)

FIG. 11 is a circuit diagram showing the basic arrangement of the power supply block shown in FIG. 2. V1 and V2 are output from an electromagnetic generator 6, V1 and V2 have AC waveforms which are reversed with respect to each other on the pre-stage of a rectification diode bridge 12 as shown in FIG. 12. Therefore, an arrangement in which a power-generation detection circuit 1, as shown in FIG. 13, is switched by using the V1 and V2 to charge the capacitor 3 is considered. The same reference numerals as in FIG. 2 denote the same parts in FIG. 11, and a detailed description thereof will be omitted.

V1 output from the electromagnetic generator 6 is supplied to the gate of the MOS transistor 2, and V2 output from the electromagnetic generator 6 is supplied to the gate of a MOS transistor 2a. As is apparent from FIG. 13, when the MOS transistor 2 and the MOS transistor 2a are alternately turned on/off, the number of times of switching is twice the number of times of switching in, e.g., the arrangement shown in FIG. 2. As a result, the charging time of the capacitor 3 becomes short, and the potential of V3 can more rapidly reach Vss if power generation continues. Therefore, the rise time of the power-generation detection signal Vout can be shortened.

Although Embodiment 9 described above is applied to the arrangement of Embodiment 1, Embodiment 9 may be applied to not only the arrangement of Embodiment 1, but also the arrangement of Embodiment 2 to Embodiment 8 as a matter of course.

In each of Embodiments 1 to 10, as the power-generation device 6, an electromagnetic power-generation device is used which transmits rotating motion of the rotating weight 7 to the rotor 10 and rotates the rotor 10 to cause the output coil to generate electromotive force. However, the power-generation device 6 is not limited

to the above power-generation device, and power-generation devices having the following arrangements may be used. That is, rotating motion is generated by recovery force of a spring to generate electromotive force by the rotating motion, and vibration or displacement externally generated or generated by itself is applied to a piezoelectric member to generate electric power by a piezoelectric effect.

As the electronic device to which the power-generation detection circuit 1 is applied, not only a wrist watch but also a pocket watch or a table timepiece may be used. In addition, the power-generation detection circuit 1 can also be applied to an electronic device such as a pocket calculator, a portable telephone, a portable personal computer, an electronic organiser, or a portable radio. The power-generation detection circuit 1 may be used to recognise a charge amount of a large-capacity capacitor and provide control for preventing an over-voltage from being applied in a power-generation state.

As an application of the power-generation detection circuit 1 described above, as shown in FIG. 14, the output holding time (time in a HI state) of the power-generation detection signal Vout is counted, and the difference between the count value CNT and a time reference timepiece TCLK is always counted by an up-down counter or the like, so that a charge amount can be recognised in real time. When the charge amount is recognised, the charge amount can be notified (shown) to a user.

When a circuit such as a constant-current generation circuit which is driven by sampling to perform a low-power operation is used, this circuit is disadvantageously weak in a variation in power supply voltage (Vss). In a period in which the power-generation detection signal Vout from the power-generation detection circuit 1 described above is set in a HI state (power-generation detection state), a sampling duty of a circuit such as a constant-current generation circuit which is driven by sampling is increased, or the constant-current generation circuit is always driven, so that an erroneous operation or characteristic degradation caused by the variation in power supply voltage of the circuit can be prevented.

The large-capacity capacitor 13 shown in FIG. 1 has the following drawbacks. That is, because of the internal resistance of the large-capacity capacitor 13, voltages at both the ends of the large-capacity capacitor 13 are higher in a power-generation state then in a stationary state, and overcharging occurs. Therefore, in a state wherein the voltage of the large-capacity capacitor 13 is equal to or higher than a predetermined voltage, when power generation is detected by the power-generation detection circuit 1 (the power-generation detection signal Vout is set in a HI state), the limiter circuit is operated, so that the large-capacity capacitor 13 can be prevented from being overcharged.

[Advantages]

Since the present invention is arranged as described above, the present invention has following advantages.

When charging/discharging of a capacitor is controlled by a simple arrangement constituted by a MOS transistor, a capacitor, and an inverter circuit to detect the voltage of the capacitor, the power-generation state of a power-generation device can be detected. By using a leakage current of a pull-up resistor, a state wherein power generation is stopped can also be detected. Detection time of the power-generation detection signal Vout can be arbitrarily adjusted by connecting a current-limiting resistor in series with the capacitor or changing the capacitance of the capacitor.

When a constant-current circuit is used in place of a resistor, a small leakage current of the capacitor can be set without variation, and power-generation detection at a high precision can be performed.

When the voltage detection means is constituted by a Schmidt trigger inverter circuit, its hysteresis characteristics make it possible to perform stable power-generation detection without being influenced by a variation in voltage of the capacitor.

In addition, when the voltage detection means is constituted by a comparator circuit, an arbitrary threshold value can be set, and stable power-generation detection can be performed without being influenced by a variation in power supply voltage.

Furthermore, when the output holding time of the power-generation detection signal Vout is considered, the strength of power generation can be known according to the output holding time of the power-generation detection signal Vout.

Claims

1. A generation detection circuit characterised by comprising:

    switching means for performing a switching operation depending on a cycle of an AC power which is externally generated;
    a capacity element for storing charges depending on a switching operation performed by said switching means;
    discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and
    voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value.

2. A power-generation detection circuit according to claim 1, characterised in that said discharging

means is a resistor element

3. A power-generation detection circuit according to claim 1. characterised in that said discharging means is constituted by a constant-current circuit.

4. A power-generation detection circuit according to claim 3. characterised in that said constant-current circuit is constituted by a constant-current source and a current mirror circuit

5. A power-generation detection circuit according to claim 1. characterised by comprising a current-limiting means. connected in series with said capacity element. for limiting a charge current of said capacity element.

6. A power-generation detection circuit according to claim 1. characterised in that said voltage detection means is an inverter circuit

7. A power-generation detection circuit according to claim 1. characterised in that said voltage detection means is a Schmidt trigger inverter circuit.

8. A power-generation detection circuit according to claim 1. characterised in that said voltage detection circuit is a comparator circuit

9. A power-generation detection circuit according to claim 1. characterised in that said switching means is a transistor

10. A power-generation detection circuit according to claim 9. characterised in that said transistor is a MOS transistor

11. A power-generation detection circuit according to claim 9. characterised in that said transistor is a bipolar transistor

12. A semiconductor device characterised by comprising

    switching means for performing a switching operation depending on a cycle of an AC power which is externally generated
    a capacity element for storing charges depending on a switching operation performed by said switching means.
    discharging means. inserted in a discharging path of said capacity element. for discharging the charges stored in said capacity element. and
    voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value

13. A semiconductor device according to claim 12 characterised in that said discharging means is constituted by a constant-current source and a current mirror circuit.

14. A semiconductor device according to claim 12. characterised in that said current mirror circuit is a pair of transistors

15. A semiconductor device according to claim 12. characterised in that said switching means is a transistor.

16. A semiconductor device according to claim 12 characterised in that said transistor is a MOS transistor.

17. A semiconductor device according to claim 12. characterised in that said transistor is a bipolar transistor.

18. An electronic device characterised by comprising.

    a power-generation device for generating an AC power; and
    a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device. a capacity element for storing charges depending on a switching operation performed by said switching means. discharging means. inserted in a discharging path of said capacity element. for discharging the charges stored in said capacity element. and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value.

19. An electronic device according to claim 18. characterised in that said power-generation device has a rotating weight for performing swing motion and a power-generation element for generating electromotive force by rotating motion performed by said rotating weight

20. An electronic device according to claim 18. characterised in that said power-generation device has an elastic member on which deformation force acts. rotating means for performing rotating motion by recovery force generated by causing said elastic member to return to an original shape. and a power-generation element for generating electromotive force by the rotating motion of said rotating means

21. An electronic device according to claim 18. characterised in that said power-generation device has a piezoelectric element which generates electromotive force by a piezoelectric effect when displace-

ment acts on said piezoelectric element.

22. An electronic device characterised by comprising:

    a power-generation device for generating an AC power;
    a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device, a capacity element for storing charges depending on a switching operation performed by said switching means, discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value; and
    a control circuit for controlling power consumption of said device on the basis of a detection result of said voltage detection means.

23. An electronic device according to claim 22, characterised in that said control circuit determines that said power-generation device does not perform power generation when a voltage of said capacity element is not more than the predetermined value, and reduces power consumption of said device.

24. An electronic device according to claim 23, characterised in that said control circuit determines that said power-generation device is performing power generation when a voltage of said capacity element exceeds the predetermined value, and cancels the reduction in power consumption.

25. An electronic device according to claim 22, characterised in that said control circuit controls the power consumption of said device in consideration of the length of time in which a voltage of said capacity element exceeds the predetermined value.

26. A timepiece characterised by comprising:

    a power-generation device for generating an AC power;
    a power-generation detection circuit constituted by switching means for performing a switching operation depending on a cycle of the AC power generated by said power-generation device, a capacity element for storing charges depending on a switching operation performed by said switching means, discharging means, inserted in a discharging path of said capacity element, for discharging the charges stored in said capacity element, and voltage detection means for detecting that a voltage of said capacity element exceeds a predetermined value; and
    a timer circuit for counting time.

27. A timepiece according to claim 26, characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a wrist watch.

28. A timepiece according to claim 26, characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a pocket watch.

29. A timepiece according to claim 26, characterised in that said power-generation device, said power-generation detection circuit, and said timer circuit are accommodated in a housing of a table clock.

30. A power-generation detection method characterised by comprising:

    the first step of performing a charging operation to a capacity element by a switching operation depending on a cycle of an AC power which is externally generated;
    the second step of performing a discharging operation of said capacity element when a charging operation is not performed to said capacity element;
    the third step of determining whether a voltage of said capacity element is a predetermined voltage; and
    the fourth step of determining that power generation is performed when the voltage exceeds the predetermined voltage.

31. A power consumption control method characterised by comprising:

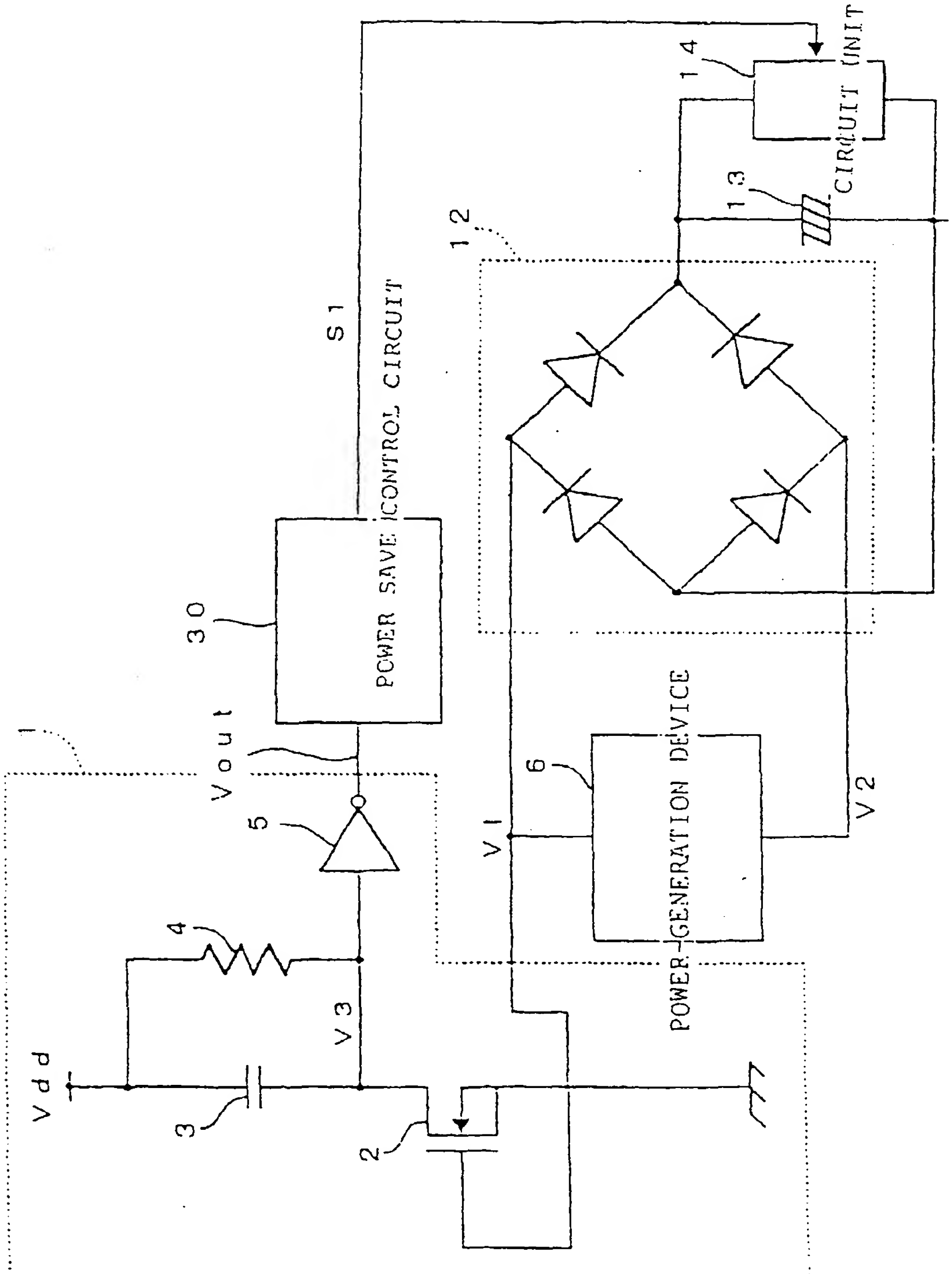
    the first step of performing a charging operation to a capacity element by a switching operation depending on a cycle of an AC power which is externally generated;
    the second step of performing a discharging operation of said capacity element when a charging operation is not performed to said capacity element;
    the third step of determining whether a voltage of said capacity element is a predetermined voltage;
    the fourth step of determining that no power generation is performed when the voltage does not exceed the predetermined voltage; and
    the fifth step of reducing power consumption of a circuit unit when no power generation is performed.

32. A power consumption control method according to claim 31 characterised by comprising

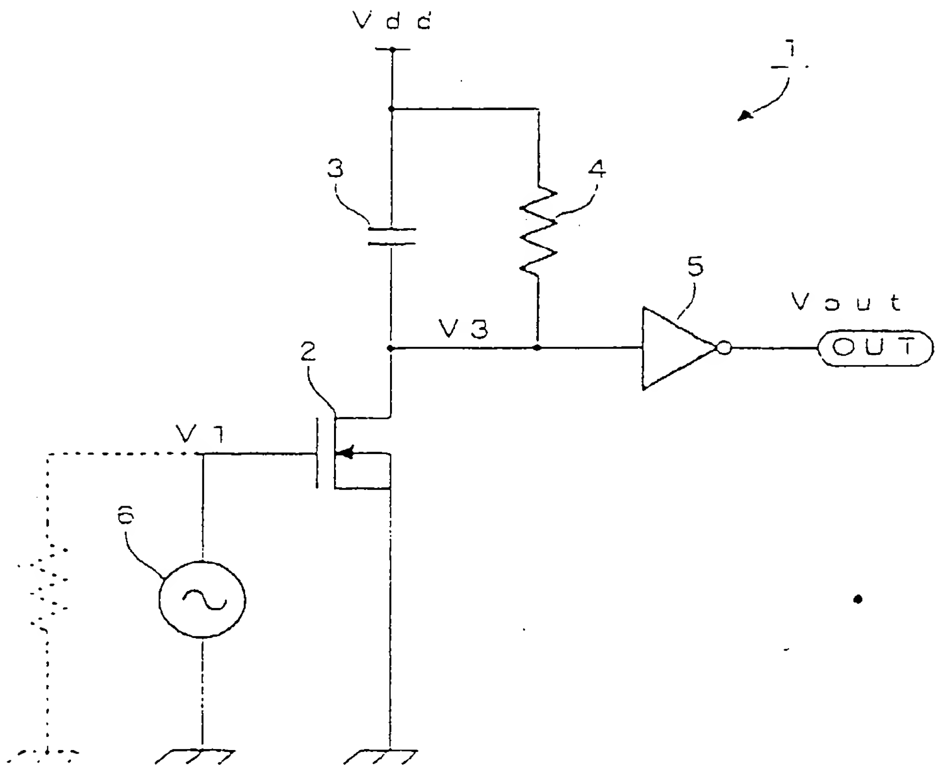
the sixth step of determining whether time in which the voltage exceeds the predetermined voltage continues for a predetermined period of time: and

the seventh step of cancelling a reduction in power consumption of said circuit unit when the time continues for the predetermined period of time.

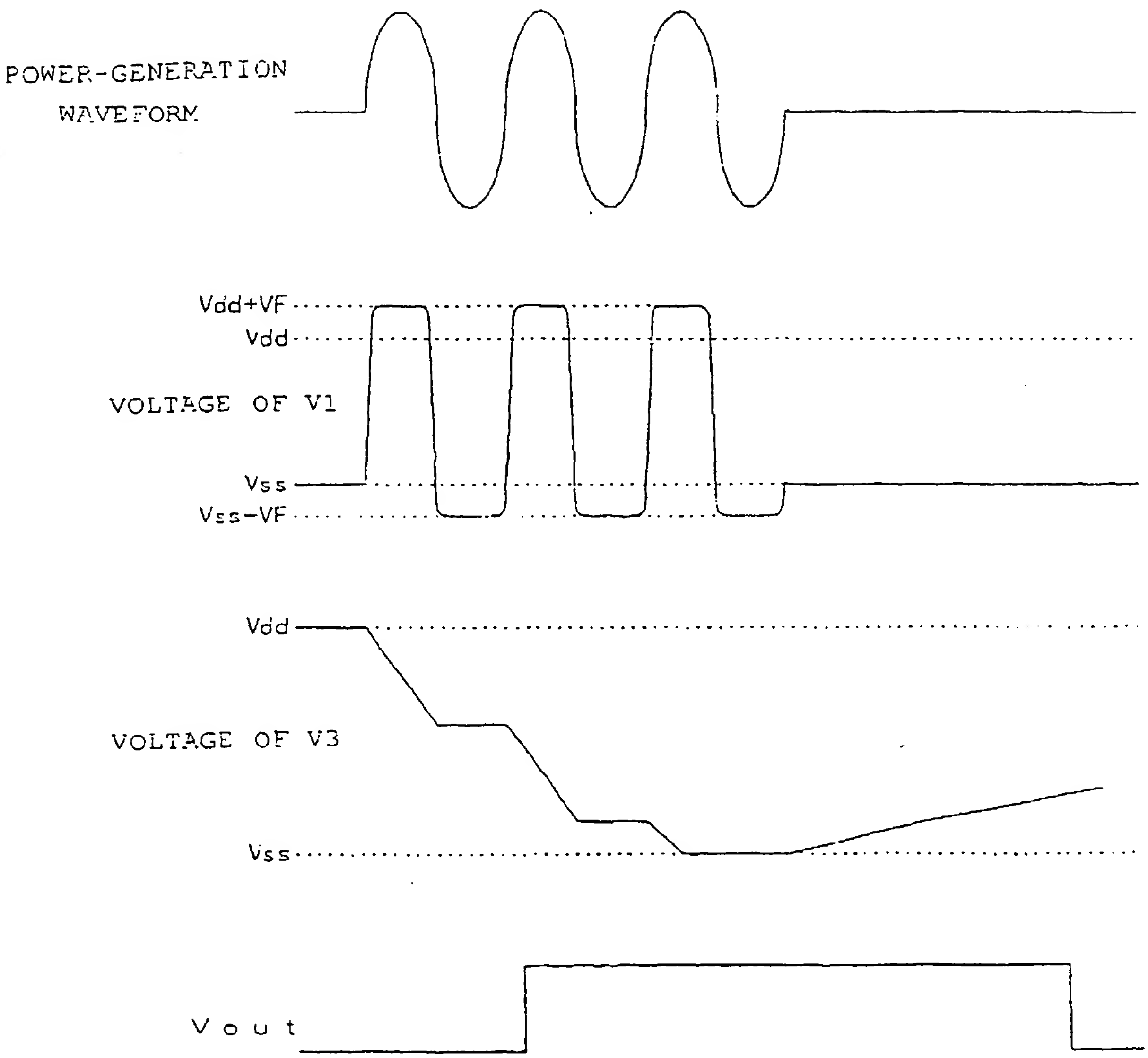
[FIG. 1]


S1
POWER SAVE CONTROL CIRCUIT
30
CIRCUIT UNIT
14
13
12
POWER GENERATION DEVICE
6
V1
V2
Vout
5
4
1
V3
Vdd
3
2

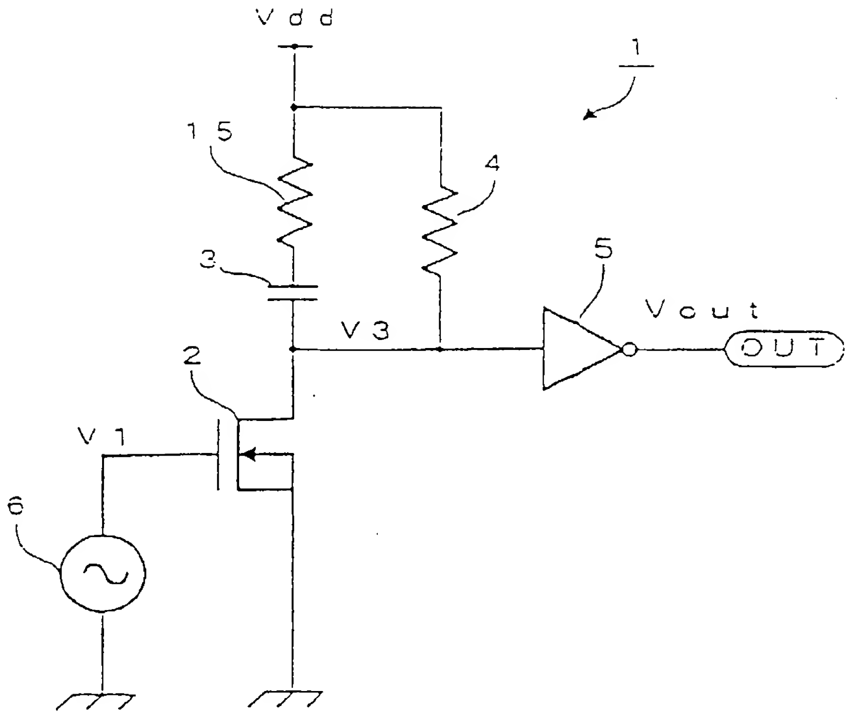
[FIG. 2]



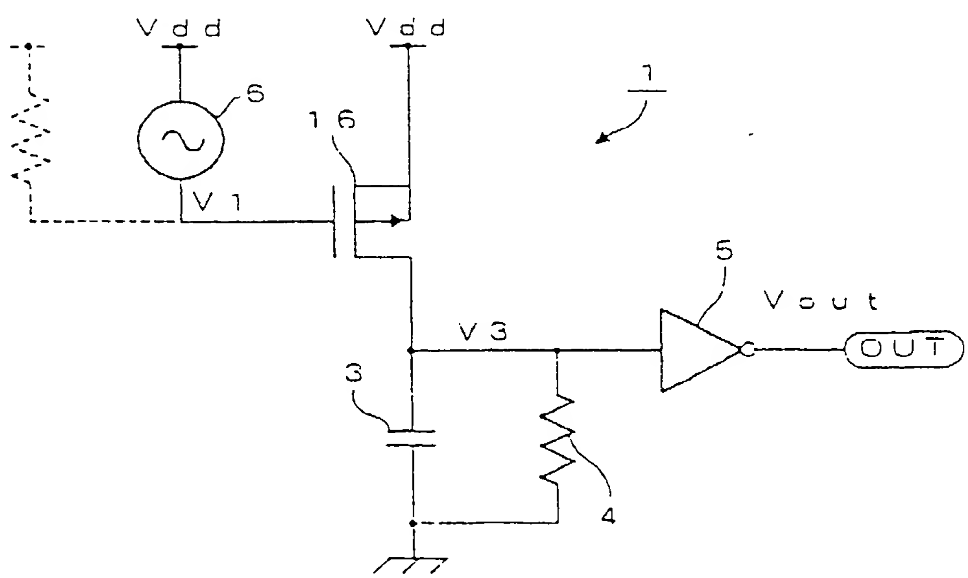
[FIG. 3]


POWER-GENERATION
WAVEFORM
Vdd+VF
Vdd
VOLTAGE OF V1
Vss
Vss-VF
Vdd
VOLTAGE OF V3
Vss
Vout

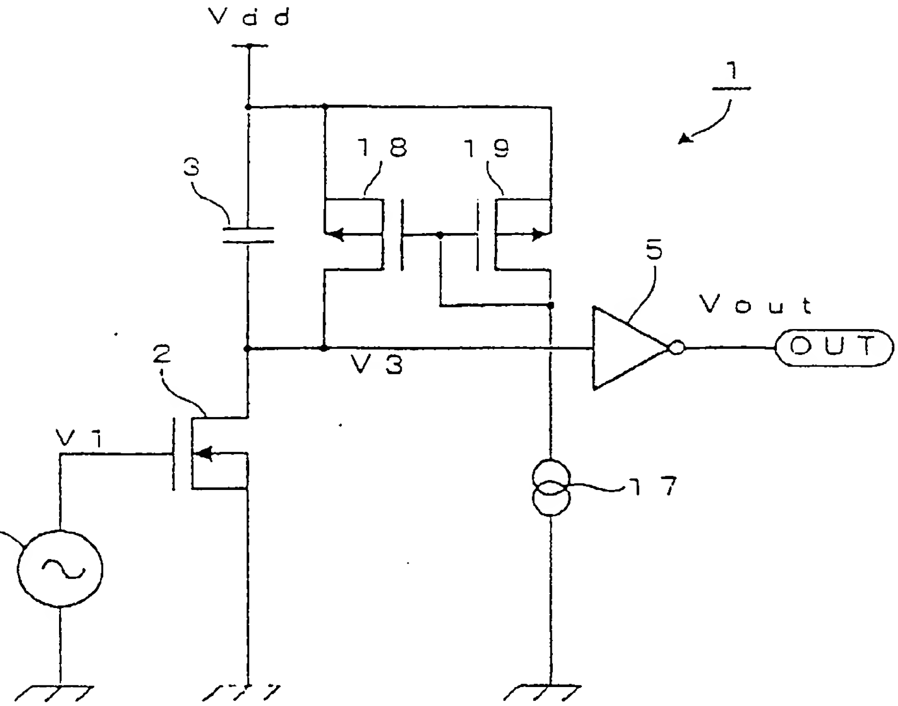
[FIG. 4]



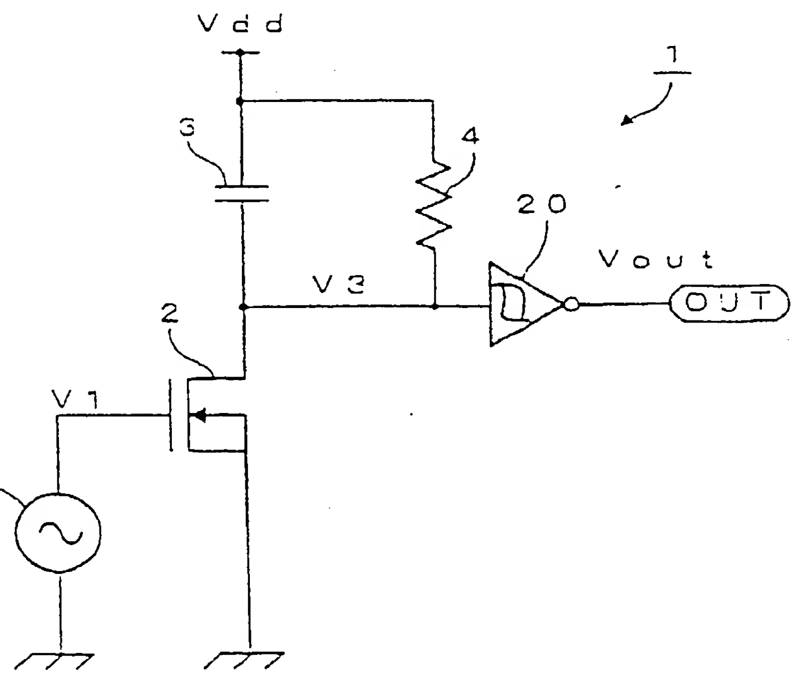
[FIG. 5]



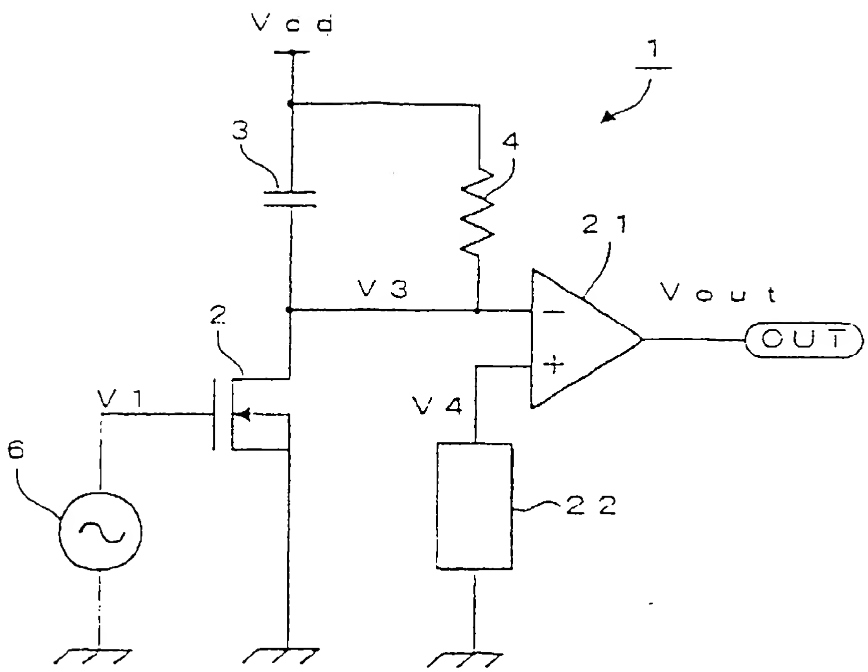
[FIG. 6]



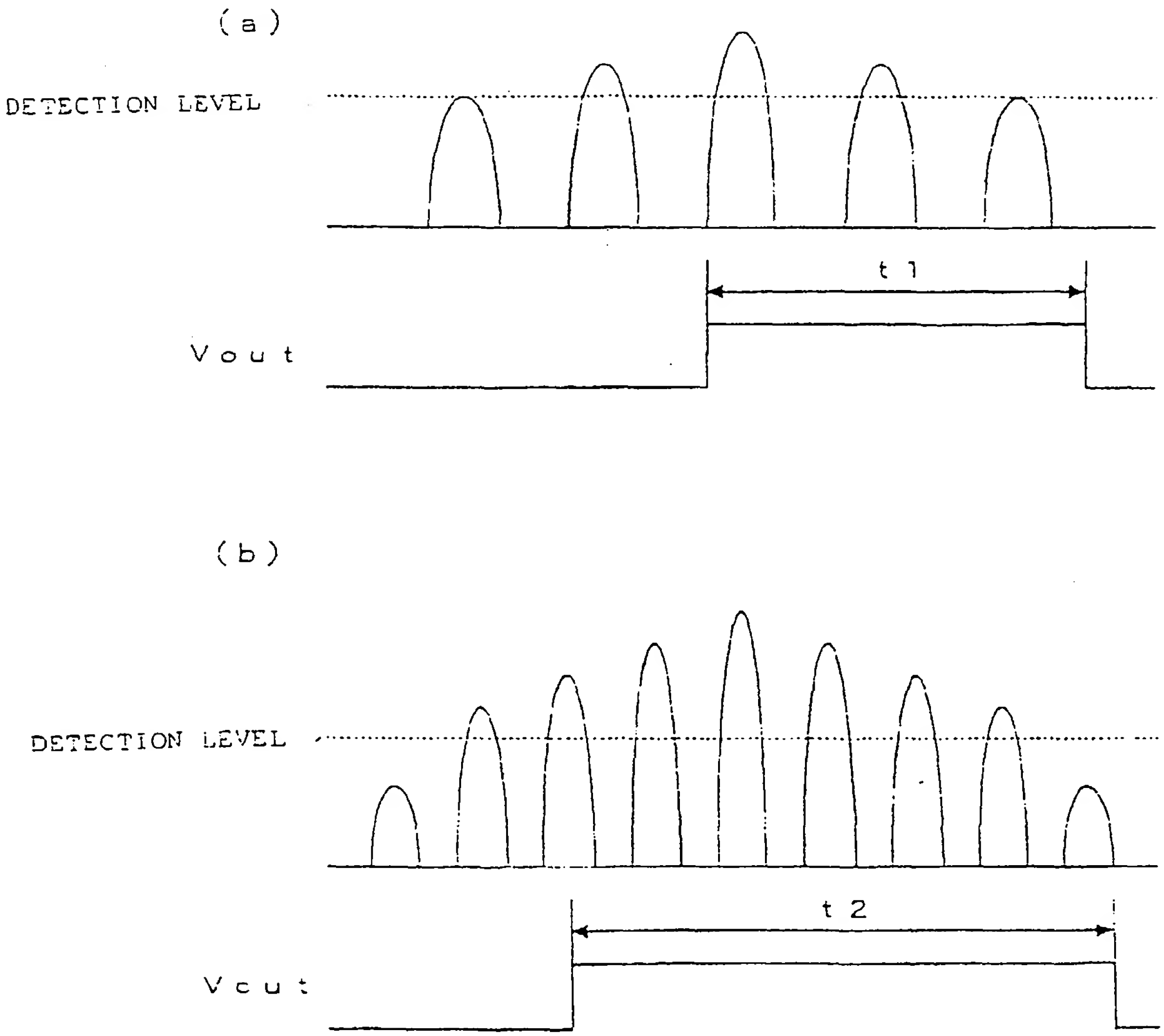
[FIG. 7]



[FIG. 8]



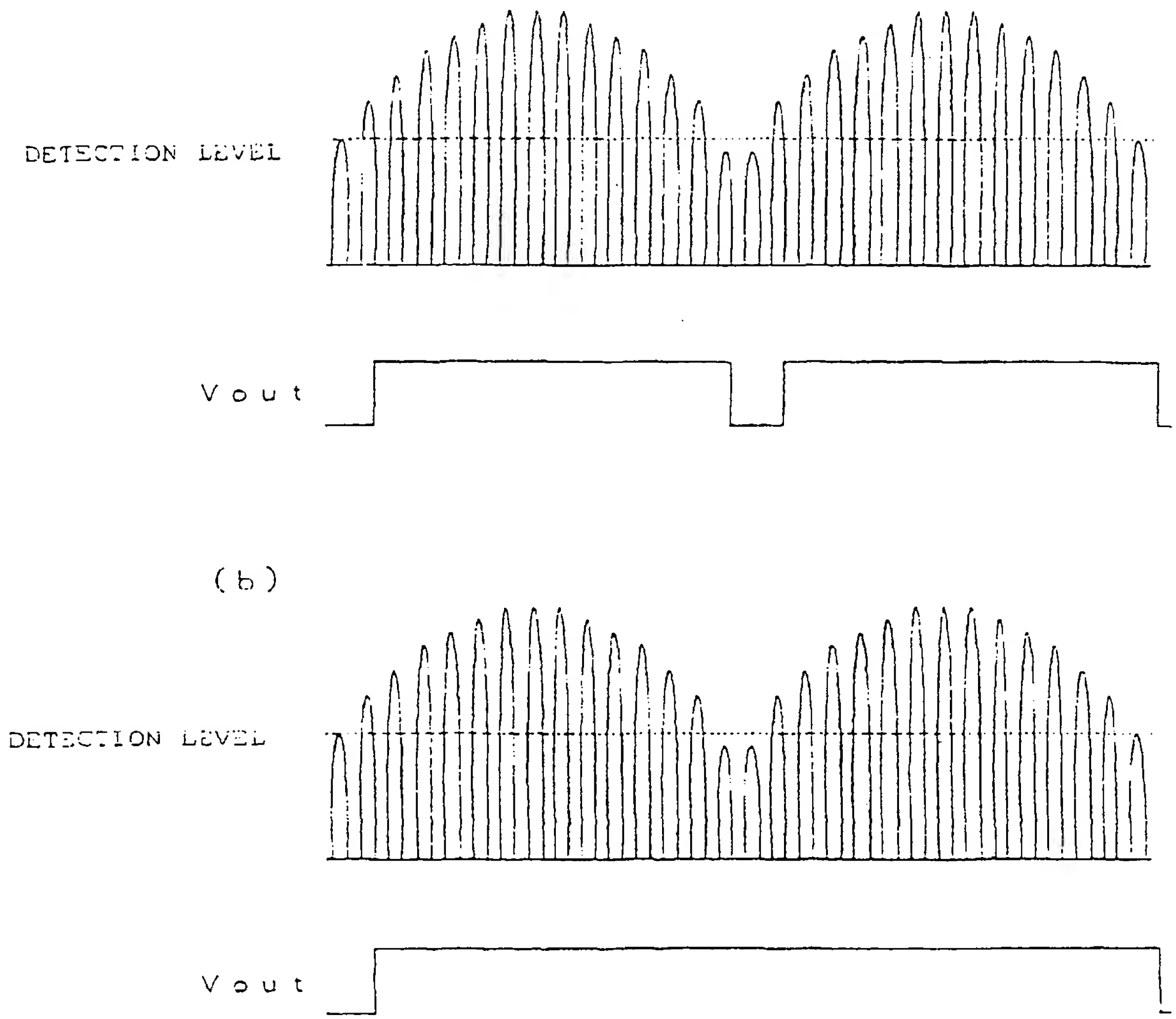
[FIG.9]



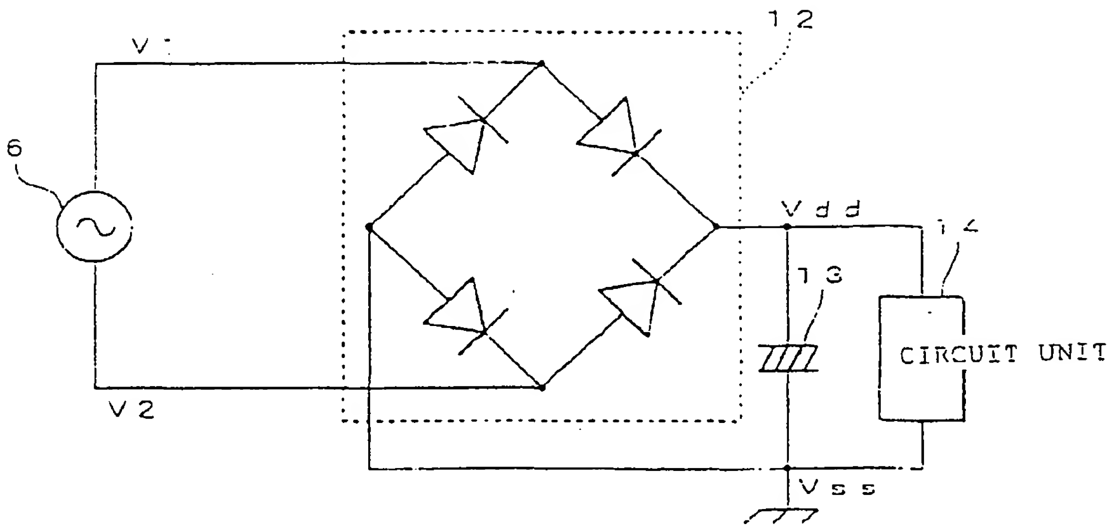
[FIG. 10]

(a)

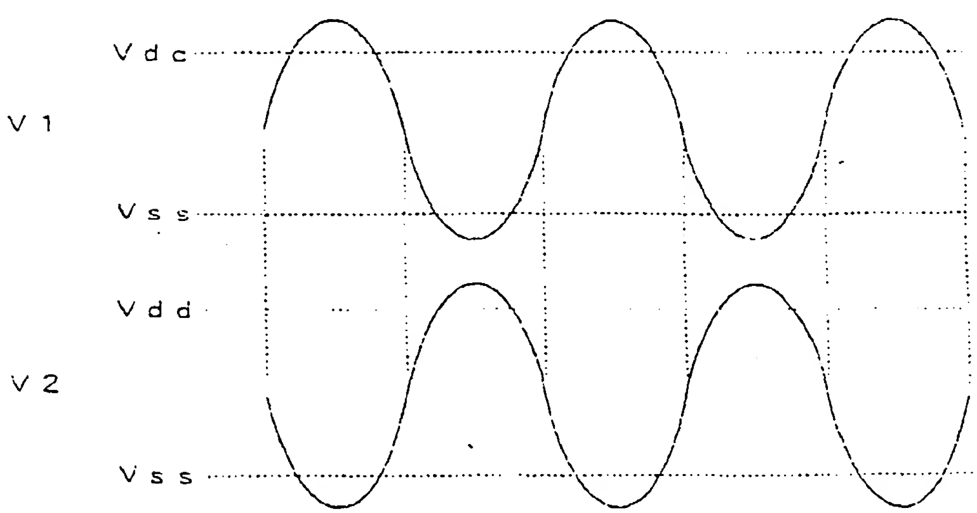
(b)



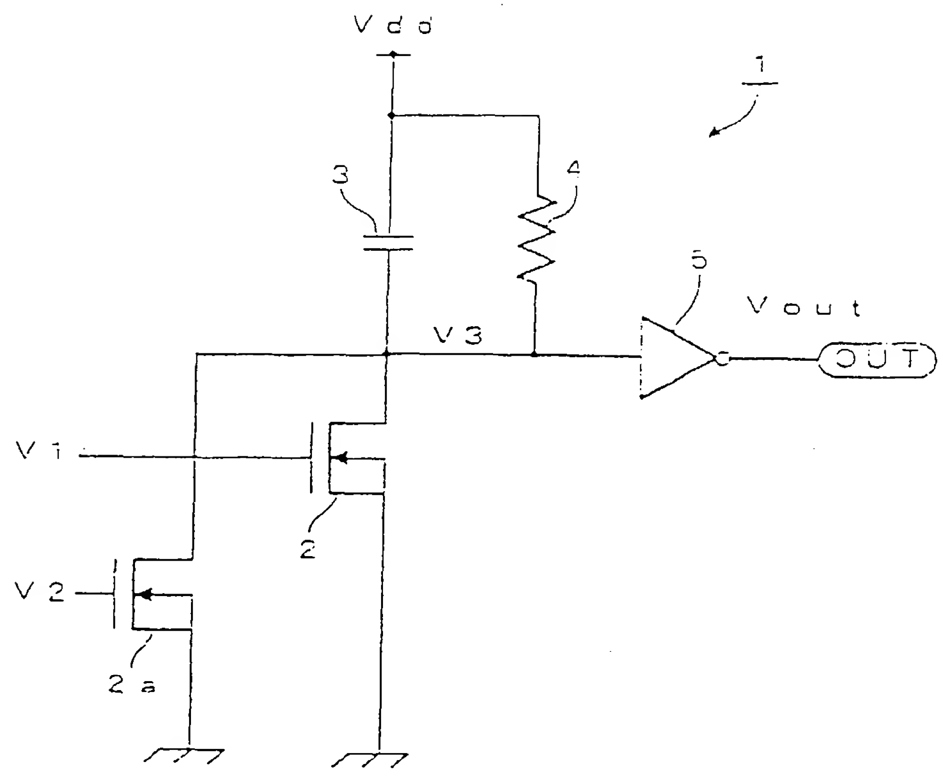
[FIG. 11]



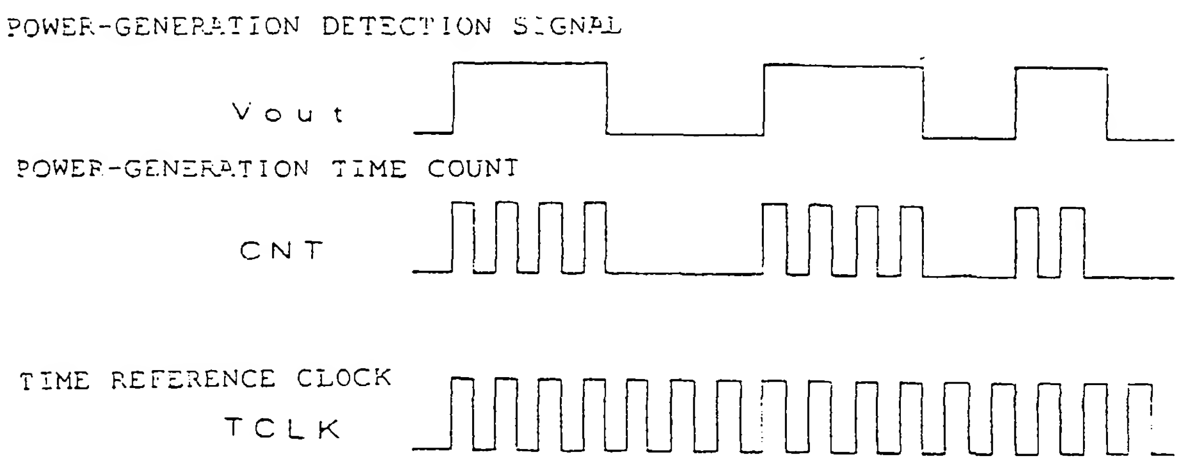
[FIG. 12]



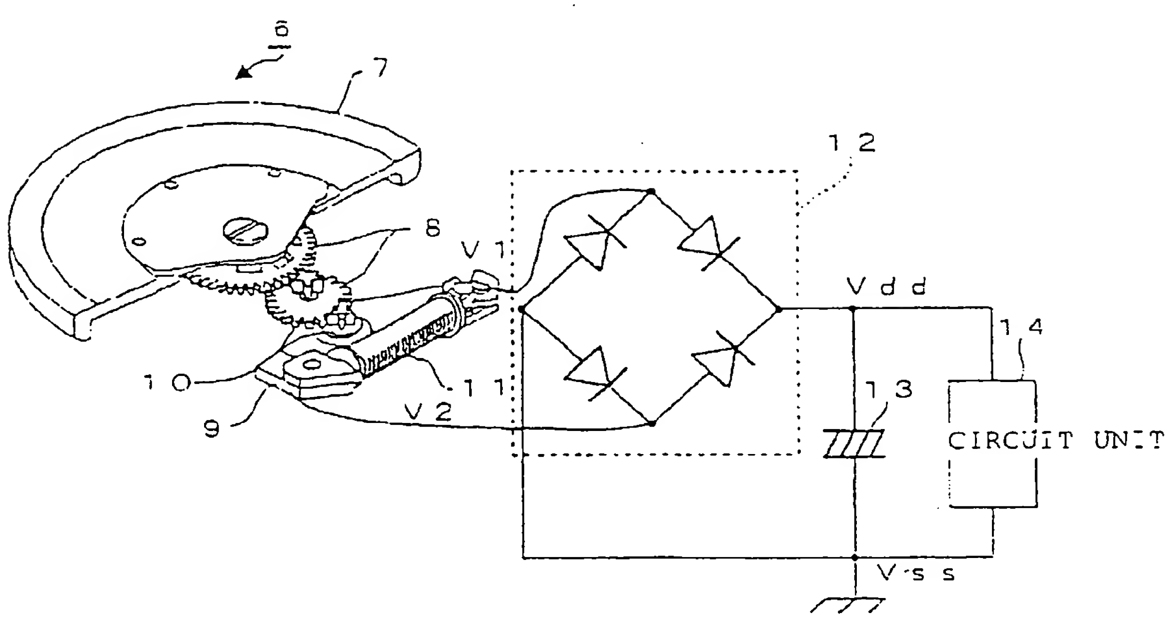
[FIG. 13]


Vdd
1
3
4
5
Vout
V3
OUT
V1
2
V2
2a

[FIG. 14]


POWER-GENERATION DETECTION SIGNAL
Vout
POWER-GENERATION TIME COUNT
CNT
TIME REFERENCE CLOCK
TCLK

[FIG. 15]



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 30 4793

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP 0 208 986 A (JUNGHANS UHREN GMBH) 21 January 1987 * claims 1-5 *	1-32	G04C10/00
Y	PATENT ABSTRACTS OF JAPAN vol. 007, no. 253 (P-235), 10 November 1983 & JP 58 137784 A (SUWA SEIKOSHA KK), 16 August 1983 * abstract *	1-32	
Y	US 3 721 832 A (LEE A) 20 March 1973 * column 2, line 15 - column 3, line 10 *	1-32	
A	PATENT ABSTRACTS OF JAPAN vol. 095, no. 001, 28 February 1995 & JP 06 300865 A (SEIKO INSTR INC), 28 October 1994 * abstract *	1-32	
A	US 4 173 756 A (KAWAGAI KENJI ET AL) 6 November 1979 * column 2, line 26-44 *	1-32	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G04C G04G
A	US 3 911 360 A (KIMZEY GENE A) 7 October 1975 * column 3, line 44-64 *	1-32	
A	EP 0 285 838 A (JUNGHANS UHREN GMBH) 12 October 1988 * claims 1-12 *	1-32	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 September 1998	Exelmans, U

CATEGORY OF CITED DOCUMENTS

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Y particularly relevant if combined with another document of the same category
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O non-written disclosure
P intermediate document

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D document cited in the application
L document cited for other reasons
& member of the same patent family, corresponding document